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Impact of Climate Variability on Yam Production in Benue State: an Empirical Analysis

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Abstract

Yam, an important root crop indigenous to the people of West Africa is popularly grown in Nigeria especially among the people within the river Benue valley. Yam contributes to more than 200 dietary calories per daily consumption as staple food, means of energy and source of income for the people. However, its production and survival is heavily dependent on variability of climatic conditions like temperature and rainfall, because of low level of technology in the country. This study employs quantitative approach using multi-linear regression model and descriptive statistic to determine the impact of dependent variable (yam production data) and independent variables (temperature and rainfall data). The findings reveal that moderate rainfall and temperature (sunshine and humidity) have correlation, positive and preponderate effect on yam production, while extreme rainfall and humidity destroy yam seedlings which adversely affect production leading to food shortage. The paper recommends that yam farmers' especially rural farmers and other stakeholders in yam production activity be made aware of conditions of climate variability to avert consequences resulting to low production. In conclusion government should introduce new improved yam breeding programmes/technology, employ modern farming tools and avail farming inputs/credit facilities to farmers to expand and enhance their efficiency in yam production to ensure profitability of yam sales.

Keywords: *Impact, Climate variability, Regression, Income and Benue State.*

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Background to the Study

Agriculture is the biggest single industry in many developing countries of the world. It contributes to the gross national product and provides not only food but also raw materials for industries of these countries as well as source of income and employer of labour for producing communities (Nahanga and Becvarova, 2015).Agriculture being the most weather dependent of all human activities is highly vulnerable to climate change and variability has direct impact on the quantity and quality of its production (Olufemi and Jonathan 2010). This is why climate of an area is highly correlated to the vegetation and by extension the type of crop that can be cultivated. Agriculture in Nigeria depends highly on climate variability, because of its low level of technology as temperature, sunlight, water, relative humidity and soil constitute the main drivers of crops growth and yield (Srivastava, Mboh, Gaiser and Ewert, 2017; Aigheuri and Maroya, 2014). Being acclaimed the world's largest producer of yams, Nigeria accounts for over 70–76 percent of the world production. The Food and Agricultural Organization (2014), reported that Nigeria produced 18.3 million tonnes of yam from 1.5 million hectares of land, representing 73.8 percent of total yam production in Africa. Accordingly, yam production in Nigeria has nearly doubled since 1985, to 35.017 million metric tonnes with value equivalent of US$5.654 billion. This accounts to 95% of the world's output of 34 million metric tonness of yams produced in 2001of which Nigeria produced 75%of the total output.

In the opinion of scholars, yams in Nigeria constitute staple food and contribute more than 200 dietary calories per daily consumption for more than 100 million people as well as significant source of income to the farmers (Adesiyan, Adesiyan, and Adebayo, 2015; Hahn, Osru, Akoroda and Otoo, 2016). It is further averred that medically, yam tuber has numerous health benefits such as healing of skin diseases, source of vitamin B6, support female endocrine system among others and contains pharmacologically active substances such as dioscorine, saponin and sapogenin (Eka, 1985 and Amuda, 2016). Dioscorine which is the major alkaloid in yam is medicinally a heart stimulant while saponin has bioactivities and of therapeutic uses (Hahn et al, 2016). Saponin has been used as adjuvant in vaccines, together with immunotoxins act as cure for leukaema, lymphoma and other cancers. Also, yam tuber is a good source of energy mainly from the carbohydrate contents since it is low in fat and protein (Ibana, .Coyne, Claudius-Cole, McNamera and Morse, 2012).

Yam is a common name for plant species in the genus of Dioscorea (family of Dioscoreaceae). According to Martin (1973) and Olorunsanya (2015), (Dioscorea has over 600 species of which about six are identified as economically important staple and edible as major source of carbohydrate to man's diet. The edible species are Disocorea rodundata (white guinea yam), Dioscorea alata (yellow yam), Dioscorea bulbifera (aerial yam), Dioscorea dumentorum (trifoliate yam), Dioscorea japonica (Japanese yam) and Dioscorea esculant (Chinese yam). Out of these Dioscorea rotundata (white yam) and Dioscorea alata (water yam) are species widely grown in the coastal region of rainforest, wood savanna and southern savanna habitats (Udemezue and Nnabuife, 2017).

Although Nigeria is recognized as the leading producer of yams in the world, however Benue State situated in the Benue valley of Nigeria with alluvial fertile land is where most of the yams are produced (Shehu ,Iortyer, Mshelia and Jongur, 2010; Benue State Agricultural and

Rural Development Agency (BNARDA, 2015). However, BNARDA annual records of 2013, 2014 and 201showed low output of yam production in the state, as a problem of climate variability. This is because yam farmers in the state lack in-depth knowledge of the effects of temperature and rainfall variability on yam production.

This paper seeks to assess the impact of seasonal temperature and rainfall variability on yam production in Benue State from 2000 to 2015 based on observation and secondary data, considering the natural phenomenon of a low technology environment. The problem is how to expand yam production to increase outputs and sales, to enhance income earnings of yam farmers and augment internal revenue generating for socio-economic development of the state

Literature Review

Conceptual Framework

The study applies the systems theory to explain the relationship between the concept of radiated heating, human activities, greenhouse gases (GHGs) and agriculture. Natural greenhouse gases (GHGs) which include water vapour, CO2, CH4 and N2O have the property of permitting the fairly free passage of short wavelength solar radiation from the sun to the earth's surface, by absorbing re-radiated terrestrial radiation from the earth (Ayoade, 2014). These greenhouse gases play crucial role in regulating the temperature of the earth and the earth's atmosphere such that the absence of these gases would have amounted to an average surface temperature of 33°C colder that is 18°C instead of the present value of 150°C (Oluwasusi, 2012). This effect known as greenhouse effect is an essential component of the regulating mechanism which has maintained the earth's climate, and makes the planet habitable, (Nnodu, 2010 and Oluwasusi, 2012). The natural effect is now becoming intensified by the presence of human induced, synthetic chemicals such as chlorofluorocarbons (CFCs), hydrofluoric carbons (HFCs), per Fluorocarbon (C5F) and sulphur hexafluoride (SF6), which also have the property to absorb terrestrial re-radiated long wave radiation and further heat up the lower troposphere atmosphere to the extent that the “artificial greenhouse gases” pose great threat to humanity (Aigheuri and Maroya, 2014).

Human activities have strongly influenced the concentrations of the naturally occurring principal GHGs (CO_2, CH4, and N2O) as stated by Warrick and Riesan, (1983) cited in Ayoade (2014). Agriculture and clearing of forest (deforestation) are responsible for nearly 50% of human generated CH_4 emissions and about 70% of anthropogenic N2O emissions (Craudfurda, Elisha, Porte, and Prasada, 2000). These human activities and their resultant outcome can be viewed as a complex system that exhibits interactions among its components and the non-linearity of these interactions. In their work on evidences of climate change in Nigeria, Odjugo and Atedhor (2007) modeled the conceptual framework on climate change as depicting mean monthly and annual climatic data (air temperature and rainfall).

A change in temperature and rainfall intensity can be disastrous to agricultural practices since increase rainfall and low temperature can result to flooding of farm lands and cause a resultant low productivity. Equally reduced rainfall and high temperature can result in drought which also brings about low productivity. This is because most crops like yams have their tolerance limit as regards water availability and temperature range. When these tolerance limits are exceeded, the survival of the crops will be threatened and this will have a resultant effect on the crop yield in terms of output (Ejikeme and Akpabio, 2017). This is not in spite of non-climatic and man-made conditions such as fertilizer pesticides among others to improve yield.

Empirical Framework

Climate change scenario is derived from two global circulation models (GCMs) and six different crops. Appate, Ogunyinka, Sanusi, and Ogunwande (2010) studied the effects of climate change and elevated CO2 on cropping systems in two Russian locations (namely Modena and Foggia). The result suggests that the combined effects of elevated atmospheric CO2 and climate change at both sites would depress crop yield if current management practices are not modified. Specifically warmer air temperature accelerates plant phonons, reduces dry matter accumulation and crop yields by 10-40%. By investigating adaptation strategies, they found out that a combination of early planting for spring summer crops and the use of slower maturing winter cereal cultivars succeed in maintaining crop yields at current levels at both sites, for irrigated maize and soya bean production at Modena. 60-90% more irrigation water was required under climate change to keep grain yields at current levels.

Trueblood and Arande. (2001) used mathematical models combining available data on the biology of agricultural crops and their response to climatic condition in their study of adaptation principles of agriculture to climate change. They calculated the potentials and meteorologically possible yields under existing environmental conditions, using the potato dynamic model, POMOD. Their result shows that under different climate change scenarios (HADCM2 and ECHAM3TR) mean potato yields will increase by about 6 to 8%. The increase is larger (10 to 16%) on Coastal Islands. Dhakhwa and Campbel (1998), who studied the potential effects of differential day-night warming in climate change on crop production, used a physically based scenario of asymmetric warming combined with climate change scenarios from General Circulation Models (GCMs) outputs and Erosion Productive Impact Calculator (EPIC) plant process model to examine the effects of asymmetric temperature change on crop productivity. Their results indicate that the potential effects of global change on crop productivity may be less severe with asymmetric day-night warming than with equal day-night warming. Nwajuba and Onyeneke (2010) in their study of effects of climate on agriculture in sub-Saharan Africa observed decreasing trends for rainfall and relative humidity and increasing trend for temperature and sunshine hours. However, the study predicts that changes in yield are low since they fall below 500 kg ha^{-1}.

Srivastava *et al.* (2017) studied the trends of agriculturally-relevant rainfall characteristics among small-scale farmers in Ghana. They used time series of daily rainfall data from 1960-2007 to identify the trends, temporal distribution, occurrence of extreme daily rainfall, the onset of rains, risk of dry spells and coefficient of variability of rain. The study notes several outcomes which the following agree with Orewa et al, (2012) stochastic analysis of yam production in Edo state:-

i. There were no significant change in the current onset of rains
ii. A decrease in the number of rain days and
iii. The probability of dry spells of up to seven and eleven days in the first four weeks of the planting season. These are applicable to the Benue State environment.

Research Methodology

The study design applies time series data of temperature and rainfall for analysis to determine trends, fluctuations and variability based on the study area.

Secondary data for weather (temperature and rainfall) are obtained from the Nigerian Meteorological Agency Headquarters, Tactical Air Command Makurdi Airport while yam production data is collected from Benue State Agricultural and Rural Development Authority Agency (BNARDA), Makurdi as well as journals and other publications.

Model Specification

The study employs multiple linear regression model (Gujarati, 2013), to determine the impact in the relationship between yam production and the variability's that exist between rainfall and temperature in Benue State from 2000 to 2015.

The model is specified as:

$$Y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ \dots \ + \mu \ \dots\dots\dots\dots \ (1)$$

Where, Y_i Yam output at time i

x_1 Temperature

x_1 Rainfalls

μ Stochastic term

$\beta_o \beta_1$ *and* β_2 = constants

Data Presentation and Analysis

Table 1: Yam Production in 000 MT Annual Temperatures (°C) and Annual Rainfall 000 (mm) for Benue State from 2000 to 2015.

Year	Yam Production 000 Metric tons	Annual Totals of Temperature (°C)	Annual Total Rain 000 (mm.)
2000	2868.86	403.2	1173.7
2001	2873.36	401.00	1082
2002	2865.36	404.39	1281.5
2003	2870.71	379.50	761.5
2004	2854.01	394.20	917.7
2005	2881.98	391.20	871.3
2006	2794.34	412.5	1343.3
2007	2802.21	401.90	1339.9
2008	2703.73	418.20	1550.5
2009	2802.80	402.70	1402.5
2010	2857.22	402.10	1331.3
2011	2869.90	395.80	1151
2012	2411.45	411.80	1492.8
2013	2533.80	399.90	1287.8
2014	2655.70	397.20	1266
2015	2874.80	392.9	1000

Source: Nigerian Meteorological Agency, Headquarters Tactical Air-Command, Makurdi-Airport and Benue State Agricultural and Rural Development Authority (BNARDA), 2015.

The variations from the years depicted from this table show the reaction of yam production to rainfall and temperature. In year 2000 the rainfall was higher than that of 2001 and the Yam production reduced. This reveals that the higher the rainfall the lower the yield.
The temperature also showed variation. The temperature of year 2000 was higher than that of year 2001. This is clear that the higher the temperature the higher the rainfall respectively.

Table 2: Yearly Rainfall Total (in mm), Annual Mean and Annual Average (in mm) and Total Wet days for Benue State from 2000 to 2015

Year	Annual Total of Rainfall (mm)	Annual Mean of Rainfall (mm)	Total wet Days
2000	1173.7	97.89	73
2001	1082	90.17	73
2002	1281.5	106.79	83
2003	761.5	63.46	68
2004	917.7	76.48	71
2005	871.3	72.61	74
2006	1343	111.92	80
2007	1339.9	111.66	88
2008	1550.5	129.21	72
2009	1402.5	116.88	90
2010	1331.3	110.94	74
2011	1151	95.92	69
2012	1492.8	124.4	89
2013	1287.8	107.32	90
2014	1266	105.5	85
2015	1000	83.33	67

Source: Nigerian Meteorological Agency and Tactical Command Markurdi, 2015.

Table 3 Shows annual rainfall totals and annual mean (in mm) for Benue State from 2000 to 2015 as is been observed with 1,492.8 (mm) both the total rainfall and the mean, the lowest rainfall is recorded in year 2003 with the record of 761.5 mm.

Table 3: Monthly Rainfall Total for Benue State from 2000 to 2015

Months	J	F	M	A	M	J	J	A	S	O	N	D
Sum	56.2	116.3	191.6	1345.9	2140.7	2629.9	2636.1	3608.1	4182.7	2113	151.5	14.8

Source: Meteorological Agency and Tactical Command, Markurdi, 2015.

Table 3: It is been observed from Table 3 that monthly rainfall total for all the years show a gradual increase of rain from April to June, April records a total rainfall of 1,345.mm. May records 2,140.7mm and June has 2,629.9mm then it progresses to the peak in September with sum amount of 4,182.9mm of planting in order to achieve a maximum yield and output.
The amount of rainfall in the study area from the months of January, February and March are not significant for planting. As noted, December has the lowest amount of rainfall.

Table 4: Average monthly rainfall Total for Benue State from 2000 to 2015

Months	J	F	M	A	M	J	J	A	S	O	N	D
Average	3.51	7.27	11.10	84.12	133.70	164.37	164.76	225.51	261.42	132.1	9.47	0.93

Source: Author's Computation

The average monthly rainfall in Benue State from 2000 to 2015 as shown in the Table 4 has the same pattern with the total monthly rainfall and the information is the same; but here the differences of rainfall in the study area in between the same months is shown in average.

Table 5: Descriptive Statistics

	Mean	Std. Deviation	N
Yam production	11.0412	3.02409	16
Rainfall	96.2082	18.12001	16
Max temp	33.4198	.34163	16
Mini temp	22.3328	.75146	16

Table 5 above shows the average mean of the study variables. Yam production has the mean of 11.04 with the Standard Deviation of 3.02, Rainfall, Mean 96.20, Standard Deviation 18.12, max temperature on the other hand has the Mean of 33.41 with the Standard Deviation of 34 and lastly minimum temperature Mean 22.33, Standard Deviation 75.

Table 6: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.677[a]	.458	.322	2.48972

a. Predictors: (Constant), mini temp, rainfall, max temp

Table 6 above is the summary of the model which includes, relationships that exist between the studied variables thus rainfall, temperature (maximum and minimum) and yam production. This shows a positively weak relationship thus r = 0.46 (46%).
It means that climatic variables irrespective of their variations are very crucial to the production of yam in the study area.

Table 7: Dependent Variable: Yam Production Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	-112.339	97.286		-1.155	.271
	Rainfall	.052	.049	.313	1.074	.304
	Max temp	1.846	3.223	.209	.573	.577
	Mini temp	2.536	1.192	.630	2.127	.055

The coefficients in Table 7 are used to test the predictive values of all the variables in this study which include rainfall maximum temperature and minimum temperature.

Rainfall has a significant value of 304, maximum temperature has a significant value of 577 while minimum temperature has a value of 055.

The coefficients in the table shows that minimum temperature has positive effect on the annual output of yam followed by rainfall while maximum temperature has a more pronounced negative effect on yam production since the temperature of a geographical location contributes to the amount of rainfall recorded.

Between the variables, minimum temperature predict better influence on yam production followed by rainfall and lastly maximum. The results show thus:
Minimum temperature B = 63, t (2.12); $P < 0.05$
Rainfall B = .31, t (1.07); $P > 0.05$ (.30)
Maximum temperature B = .20, t (.57); $P > 0.08$ (.57)

Summary of Findings
The results from the statistical analysis tested from the three variables, maximum temperature, rainfall and minimum temperature showed thus:-

i. Rainfall: The rainfall table and yam production show little relationship but not too much that will cause flooding the result shows that Rainfall B = .31, t(1.07); $P>0.05$(.30).
ii. Minimum temperature: Minimum temperature has the highest influence on yam yield among all the variables in the work, the result shows thus, minimum temperature B = 63, t(2.12); $P< 0.05$.

The overall results show that minimum temperature has more positive effect to annual output of yam followed by rainfall while maximum temperature has a more pronounced negative effect on yam production.

Conclusion
The study examines the effects on temperature and rainfall variability on yam production in Benue State from 2000 to 2015. It is observed that the onset and cessation of rains have not been constant (there is change in onset) even though the quantity of rains received do not show much variability, but the long dry spells of 10 to 13 days has negative effect of yam in the study area. This agrees with the assertions in the literature review, on climate relations to food crops in Benue State (Shehu. et al, 2010 and Appate et al, 2010).

The trend of yam output in the study area showed fluctuations in between the years and the highest production was in 2015 with the production rate of 2874.80 metric tons and this was as a result of the variations in temperature and rainfall which showed that there is positive, but weak relationship between temperature and rainfall variability on yam production in the study area.

Recommendations

I. For Benue State to maintain the appellation of *Food Basket of Nigeria*, it has to prioritize agriculture especially yam production in which the state has comparative advantage. This is by injecting more resources to boost production such as increase in budgetary allocation, employment of more agricultural extension workers, new breeds of yam-seedlings, early supply of fertilizers, insecticides/pesticides and tractors-hiring services to farmers, among other farm inputs.

ii. With irregular rainfalls and unpredictable climatic conditions, measures should be taken through new knowledge-economy based technology and irrigation methods to forestall these uncertainties by liaising with agricultural research institutes to provide high breed yam species suitable for farmers in the study area.

iii. To add value, the Benue state government should establish a yam processing plant especially at Zaki-Biam which is adjudged the largest yam market in West Africa. This will create wealth and other externalities for the people of Benue State.

iv. There is need to aggressively invest more in water supply and expansion through modern day irrigation system by taking advantage of rivers Benue and Katsina-Ala as the largest waterways of the state.

v. Finally, these measures will reduce the uncertainties associated with the variability in climate conditions that would impact on the production of yams in the study area.

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